SPECIFICATION

RETROREFLECTION SHEETING AND FILM FOR USE IN

RETROREFLECTION SHEETING

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TECHNICAL FIELD

The present invention relates to a retroreflective sheeting with prism elements of a novel structure. More specifically, the invention relates to a retroreflective
10 sheeting comprising a reflective element layer containing triangular pyramidal frustum prism elements of a novel structure, as well as a resin film for use in the retroreflective sheeting.

15 **BACKGROUND ART**

The retroreflective sheeting is used for signboards such as road signboards and construction site signboards, car license plates of automotive vehicles such as automobiles and motorcycles, and safety materials such as collision warning
20 signboards, clothing, and life jackets.

There are proposed some techniques of obtaining retroreflection by embedding micro glass beads in a resin sheet and utilizing refraction of the glass beads (see Japanese Unexamined Patent Publication No. 6-160615, Japanese Unexamined
25 Patent Publication No. 6-347623, and Japanese Unexamined Patent

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Publication No. 9-212115). In the proposed techniques, even if an angle (hereinafter, called as "incident angle) formed between a vertical line perpendicularly intersecting a surface of the resin sheet, and light incident on the resin sheet is

5   increased, lowering of retroreflective performance (sometimes called as "coefficient of retroreflection") is suppressed (in other words, superior incident angularities are obtained). However, in the above arrangement, the absolute value of a luminance factor (i.e. a coefficient of retroreflection) is

10   small, which obstructs acquiring sufficient retroreflection. In addition to the above drawback, since segregation of the glass beads from the resin is impossible, segregation recycling is impossible, and incineration is impossible. Accordingly, disposal by landfill is the only measure, which may increase

15   environmental load.

In order to solve the above drawbacks, a triangular-pyramidal cube-corner retroreflective sheeting with elements has been proposed. With the retroreflective sheeting, segregation recycling is possible, which may reduce

20   environmental load. Also, the retroreflective sheeting provides an improved luminance factor (i.e. an improved coefficient of retroreflection), and accordingly, provides superior retroreflection against incident light of a specific incident angle. However, the incident angularities are poor.

25   In other words, the retroreflective sheeting above exhibits a

desirable retroreflective performance while the incident angle is small, but the retroreflective performance is sharply degraded as the incident angle is increased.

In the triangular-pyramidal cube-corner retroreflective sheeting above, reflected light is less likely to be diffusely reflected in a wide angle, as compared with the glass beads type retroreflective sheeting. Accordingly, in practical use of the retroreflective sheeting above, in the case where light emitted from a headlamp of an automobile is retroreflected on a traffic signboard, for instance, the retroreflected light may be hard to reach the driver's eyes if the driver is located on an off-axis position of the optical axis of the retroreflected light due to the narrow diffuse angle of the retroreflected light. The drawback becomes conspicuous particularly when the automobile comes close to the traffic signboard, because the angle (hereinafter, called as "observation angle") formed between the axis of the incident light and the axis (observation axis) connecting the driver's position and a reflected point of the incident light on the traffic signboard is increased (that is, observation angularities are degraded).

A retroreflective sheeting obtained by arranging triangular pyramid type reflective elements of various shapes on a thin sheet, and a method for producing the retroreflective sheeting are proposed as an improved approach to solve the above drawbacks (see U.S. Patent No. 2,481,757). It is

described that examples of the triangular pyramid type reflective elements include a triangular pyramid type reflective element, in which the apex of a triangular pyramid is aligned with the center of a base triangle, without a tilt

5 of the optical axis, and a triangular pyramid type reflective element, in which the apex of a triangular pyramid is off the center of a base triangle, with a tilt of the optical axis, to efficiently reflect light against an approaching automobile. The method in the publication above, however, has no specific

10 disclosure about a microsized triangular pyramid type reflective element, and has no recitation on a desirable size and a desirable optical axis tilt of the triangular pyramid type reflective element.

Some approaches are proposed as a measure to solve the

15 above drawbacks by specifying the size of the triangular pyramid type reflective element, and determining a tilt of the optical axis (see Japanese Unexamined Patent Publication No. 6-250006 and Japanese Unexamined Patent Publication No. 2001-264525). However, the improvement is insufficient, and in the

20 case where the coefficient of retroreflection when both the incident angle and the observation angle are small is exceedingly large, halation which makes the recognition of a sign or the like difficult for a driver may likely occur due to too bright reflected light, whereby the driver may be misguided.

25 On the other hand, in the case of where the retroreflection is

to be improved when the incident angle is larger, the retroreflective performance (i.e. the coefficient of retroreflection) may be degraded when both the incident angle and the observation angle are small, which may fail to provide

5 sufficiently enhanced incident angularities.

Also, an attention should be paid in attaching a retroreflective sheeting on a base member in view of a drawback that the retroreflective performance is extremely varied between vertical direction and horizontal direction, in other

10 words, direction characteristics are poor. So far, there is no specific technical disclosure to solve the drawback.

Furthermore, it is necessary to provide protruding supports as a constituent member of the retroreflective sheeting having a triangular pyramid type reflective element

15 layer in order to secure an air layer on the back side of the triangular pyramid type reflective elements in firm contact with a backing film (or a backing sheet). However, the reflective element layer having the protruding supports in the firm contact with the backing sheet cannot meet the total

20 internal reflection requirement. Therefore, the retroreflective performance of the retroreflective sheeting with the triangular pyramid type reflective element layer may be degraded.

Moreover, since according to the retroreflective

25 sheetings produced by the aforementioned methods, the

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triangular pyramidal element has a very sharp apex, in attaching the backing sheet, the sharp apex may be abraded or deformed, which cause undesirable fluctuation of the retroreflective performance, and further, when the

5 retroreflective sheeting is temporarily rolled in after the prism elements are formed, the triangular pyramidal elements may be abraded in the roll, and consequently broken. Since the portion containing the broken prism elements is unusable as a product, and should be disposed of, environmental load may be

10 increased.

DISCLOSURE OF THE INVENTION

In view of the above, an object of the present invention is to provide a retroreflective sheeting that

15 exhibits proper retroreflection even at a small incident angle with no or less halation, and has superior incident angularities and superior direction characteristics, as well as a film for use in the retroreflective sheeting.

As a result of an intensive study, the inventors found

20 that a retroreflective sheeting with reflective elements (microprism elements) of a specific triangular pyramidal frustum configuration causes less halation, and exhibits retroreflection with superior incident angularities and superior direction characteristics, and accomplished the

25 invention.

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Specifically, the invention is directed to (1) to (10).

(1)   A   retroreflective   sheeting   with   triangular
pyramidal   frustum   prism   elements,   which   comprises   a
reflective element layer containing the triangular pyramidal
frustum prism elements in a close-packed state formed on one
surface of the retroreflective sheeting, and satisfies the
following requirements: the triangular pyramidal frustum
prism element has a bottom surface with one side length
thereof being in the range of 50 to 400 μm, and a difference
between a longest side and a shortest side thereof being 200
μm or less; the length of a longest edge of the triangular
pyramidal frustum prism element is in the range of 30 to 400
μm, and a difference between the longest edge and a shortest
edge among the three edges thereof is 100 μm or less; when a
vertical line which intersects perpendicularly with the
bottom surface is drawn from a top surface of the triangular
pyramidal frustum prism element to the bottom surface thereof,
the length of a longest vertical line is in the range of 20
to 250 μm; and an angle between adjacent side surfaces of the
triangular pyramidal frustum prism element is in the range of
85 to 95 degrees.

(2)   The retroreflective sheeting having the features
recited in (1), the lengths of the three sides of the bottom
surface of the triangular pyramidal frustum prism element are

different one from another.

(3)   The retroreflective sheeting having the features recited in (1) or (2), wherein the area ratio of the top surface of the triangular pyramidal frustum prism element to the bottom surface thereof is in the range of 1/100 to 1/16.

(4)   The retroreflective sheeting having the features recited in any one (1) to (3), wherein the reflective element layer is formed on a resin film having a thickness in the range of 30 to 300 µm, and a total light transmittance of. 20% or more.

(5)   The retroreflective sheeting having the features recited in any one of (1) to (4), wherein the retroreflective sheeting has a backing film made of a resin, the backing film is locally attached to a film having the reflective element layer formed thereon via protruding supports provided by emboss processing in such a manner that an air is sealed between the reflective element layer and the backing film and that a plurality of airtight chambers are formed.

(6)   The retroreflective sheeting having the features according to any one of (1) to (5), wherein the backing film is placed adjacent on the top surfaces of the respective triangular pyramidal frustum prism elements without protruding supports.

(7)   A resin film for use in a retroreflective sheeting with triangular pyramidal frustum prism elements,

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which comprises a reflective element layer containing the triangular pyramidal frustum prism elements in a close-packed state formed on one surface of the retroreflective sheeting, wherein the triangular pyramidal frustum prism element has a

5   bottom surface in the shape of a triangle, with one side length thereof being in the range of 50 to 400 μm, and a difference between a longest side and a shortest side thereof being 200 μm or less; when a vertical line which intersects perpendicularly with the bottom surface is drawn from a top

10   surface of the triangular pyramidal frustum prism element to the bottom surface thereof, the length of a longest vertical line is in the range of 20 to 250 μm; and   an   angle between adjacent side surfaces of the triangular pyramidal frustum prism element is in the range of 85 to 95 degrees.

15   (8)   The resin film having the features recited in (7), wherein the resin film is made of one or more kinds of resins selected from the group consisting of acrylic resin, polycarbonate resin, polystyrene resin, polyester resin, polyethylene resin, polypropylene resin, polyvinylchloride

20   resin, polyarylate resin, polyurethane resin, epoxy resin, fluororesin, and cellulose resin, and the resin film has a thickness in the range of 30 to 300 μm, and a total light transmittance of 20% or more, and is capable of forming the reflective element layer thereon.

(9)   The resin film having the features recited in (7) or (8), wherein the resin film contains a UV absorber selected from benzotriazols, benzophenones, triazines, or the like, a light stabilizer selected from hindered amines or the like, an antioxidant including phenols, phosphates, or the like, or a lubricant such as montanic esters or metal stearate salts.

(10)   The resin film having the features recited in any one of (7) to (9), wherein the resin film contains an organic dye such as thioxanthenes, coumarins, perylenes, methines, benzopyrans, thioindigos, or anthraquinones, or an organic pigment such as azo pigments or phthalocyanines.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing configurations and names of portions constituting a triangular pyramidal frustum prism element.

FIG. 2 is a top plan view of a retroreflective sheeting with triangular pyramidal frustum prism elements.

FIG. 3 is a diagram showing one example of the retroreflective sheeting with the triangular pyramidal frustum prism elements.

FIG. 4 is a diagram showing other example of the retroreflective sheeting with the triangular pyramidal frustum prism elements.

FIG. 5 is a conceptual diagram 1 showing a method for measuring a coefficient of retroreflection according to JIS Z8714.

FIG. 6 is a conceptual diagram 2 showing a method for 5 measuring a coefficient of retroreflection according to JIS Z8714.

Description on Reference Numerals

(a): length of side of bottom surface

10 a_1, a_2, a_3: each side of triangular bottom surface

(b): bottom surface

(c): top surface

(d): longest edge of imaginary triangular pyramid

d_1, d_2, d_3: each edge of imaginary triangular pyramid

15 (e): distance between bottom surface and top surface

e_1, e_2, e_3: each distance between bottom surface and top surface of triangular pyramidal frustum element

f_1, f_2, f_3: each angle between adjacent side surfaces of triangular pyramidal frustum element

20 (1): surface protective layer

(2): reflective element layer (triangular pyramidal frustum prism element layer)

(3): prism element containing layer

(4): backing film

25 (5): jointed site (protruding support)

(6): air layer

11: light source

12: retroreflective sample (retroreflective sheeting)

α: observation angle

5   β: projection angle (incident angle)

d: observation distance

θ: rotation angle of retroreflective sample

13: receiving aperture

14: spectral analyzer

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BEST MODE FOR CARRYING OUT THE INVENTION

A retroreflective sheeting of the invention is a retroreflective sheeting with triangular pyramidal frustum prism elements, in which a reflective element layer

15   containing the triangular pyramidal frustum prism elements in a close-packed state is formed on one surface of the retroreflective sheeting.

The reflective element i.e. a microprism element constituting the inventive retroreflective sheeting has a

20   triangular pyramidal frustum shape. Specifically, the microprism element is the triangular pyramidal frustum shape having the top surface (c), the bottom surface (b), and the three side surfaces (i.e. slant surfaces) as a polyhedron obtained by cutting a triangular pyramid (hereinafter called

as "imaginary triangular pyramid") having the triangular bottom surface (b), and three side surfaces (slant surfaces) sharing the bottom surface by a flat plane (i.e. a top surface (c)), and by removing the upper triangular pyramid

5   (hereinafter, also called as "upper portion of the imaginary triangular pyramid").

In the invention, halation that may likely occur in the case where both the incident angle and the observation angle are small can be reduced by forming the microprism elements

10   into the triangular pyramidal frustum shape. Also, this arrangement enables to prevent lowering of retroreflection without impairing the total internal reflection requirement for the microprism elements in firmly attaching a backing film. Furthermore, the arrangement enables to reduce the

15   amount of a waste material due to deformed or missing apex portions of the microprism elements, and to enhance processability on the prism elements.

The shape of the inventive triangular pyramidal frustum element is described referring to FIG. 1.

20   The bottom surface (b) of the triangular pyramidal frustum element in the invention is a triangle having the features that: one side (a) has the length in the range of 50 to 400 μm, preferably 60 to 300 μm, and more preferably 100 to 250 μm; and that a difference between the longest side and

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the shortest side is 200 μm or less, preferably 150 μm or less, and more preferably 100 μm or less.

In the case where the length of the one side (a) of the triangular bottom surface (b) is smaller than 50 μm, it is

5   difficult to process the prism elements, and incident angularities tend to be lowered. In the case where the length of the one side (a) of the triangular bottom surface (b) exceeds 400 μm, retroreflective performance tends to be lowered. In the case where a difference between the longest

10 side and the shortest side among the three sides of the triangular bottom surface (b) exceeds 200 μm, in other words, if the bottom surface (b) is an exceedingly long triangle, incident angularities tend to be lowered.

The three sides of the triangular bottom surface (b) in

15 the invention may preferably have different lengths one from another in the aspect of direction characteristics. In the case where the two of the three sides of the triangular bottom surface (b) are equal to each other, in other words, if the bottom surface (b) is an isosceles triangle or an

20 equilateral triangle, direction characteristics tend to be lowered.

The imaginary triangular pyramid for obtaining the triangular pyramidal frustum element of the invention has the features that: the length of the longest edge (d) is in the

range of 30 to 400 μm, preferably 50 to 300 μm, and more
preferably 80 to 200 μm; and that a difference between the
longest edge and the shortest edge among the three edges is
100 μm or less, preferably 90 μm or less, and more preferably

5   80 μm or less.

In the case where the length of the longest edge (d) of
the imaginary triangular pyramid is smaller than 30 μm or
exceeds 400 μm, incident angularities and retroreflective
performance tend to be lowered. In the case where a

10   difference between the longest edge and the shortest edge
among the three edges of the imaginary triangular pyramid
exceeds 100 μm, incident angularities and retroreflective
performance tend to be lowered.

The top surface (c) of the triangular pyramidal frustum

15   element of the invention is a flat plane formed by cutting
off the upper portion of the imaginary triangular pyramid,
and is a triangle defined by connecting the intersections
with the three edges of the imaginary triangular pyramid.

The triangular pyramidal frustum element of the

20   invention has a feature that the length (e) (hereinafter,
called as the longest distance (e) between the top surface
(c) and the bottom surface (d)) of a longest line among three
lines which extend perpendicularly from the respective
intersections crossing the top surface (c) with the three

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edges of the imaginary triangular pyramid to the bottom surface (b) is in the range of 20 to 250 μm, preferably 50 to 200 μm, and more preferably 70 to 150 μm.

In the case where the longest distance (e) between the
5   top surface (b) and the bottom surface (c) is smaller than 20 μm, retroreflective performance tends to be lowered; and in the case where the longest distance (e) exceeds 250 μm, incident angularities tend to be lowered.

It is preferable to set the top surface (c) of the
10   inventive triangular pyramidal frustum element parallel to the bottom surface (b). Setting the top surface (c) of the triangular pyramidal frustum element parallel to the bottom surface enables to improve front retroreflective performance due to specular reflection on the top surface (c) against
15   light incident from a front direction (i.e. light of a small incident angle). Also, the arrangement enables to prevent lowering of retroreflective performance without impairing the total internal reflection requirement for the microprism elements in firmly attaching a backing film. Furthermore, the
20   arrangement enables to enhance processability in processing the microprism elements. It is, however, allowable to set the top surface (c) of the inventive triangular pyramidal frustum element with a slight inclination relative to the bottom surface (b).

Generally, in the case where the top surface (c) of the triangular pyramidal frustum element is set parallel to the bottom surface (b), the triangle of the top surface (c) is similar in shape to the triangle of the bottom surface (b).

5   In this case, it is known that the area ratio of the triangle of the top surface (c) to the triangle of the bottom surface (b) is proportional to square of the ratio of the height of the upper portion of the imaginary triangular pyramid to an assumed height of the imaginary triangular pyramid from the

10   apex thereof.   In the triangular pyramidal frustum element having the top surface (c) parallel to the bottom surface (b), the longest distance (e) between the top surface (c) and the bottom surface (b) is obtained by subtracting the height of the upper portion of the imaginary triangular pyramid from

15   the assumed height of the imaginary triangular pyramid.

In the triangular pyramidal frustum element of the invention, the area of the top surface (c) is preferably in the range of 1/100 to 1/16 relative to the area of the bottom surface (b), and more preferably in the range of 1/80 to 1/25.

20   In the case where the area ratio of the top surface (c) to the bottom surface (b) is smaller than 1/100, adhesiveness to a base member tends to be lowered.   In the case where the area ratio of the top surface (c) to the bottom surface (b) exceeds 1/16, retroreflective performance tends to be lowered.

25   The angle (f) between the adjacent side surfaces of the

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triangular pyramidal frustum element of the invention is in the range of 85 to 95 degrees, preferably 88 to 93 degrees, more preferably 89 to 91 degrees, and most preferably 89.05 to 90.05 degrees. In the case where the angle between the

5 adjacent side surfaces of the triangular pyramidal frustum element is smaller than 85 degrees or exceeds 95 degrees, retroreflective performance tends to be lowered.

The size of the triangular pyramidal microprism elements of the invention may be uniform or varied.

10 Generally, the retroreflective sheeting with the triangular pyramidal frustum elements of the invention is produced by transferring a triangular pyramidal frustum type microprism pattern onto a flexible and optically transparent resin sheet (resin film), using a molding die (female die)

15 having a metallic die in which an inverted pattern of the triangular pyramidal frustum type microprism pattern is concavely formed in a close-packed state. The resin sheet (resin film) for forming the triangular pyramidal frustum microprism elements to be used in the invention has a

20 thickness in the range of 30 to 300 μm, preferably 50 to 250 μm, and more preferably 100 to 200 μm, and a total light transmittance of 20% or more, preferably 30% or more, and more preferably 60% or more.

In the case where the thickness of the resin sheet

(resin film) is smaller than 30 μm, defects such as pinholes may likely to be generated in forming the prism pattern. In the case where the thickness of the resin sheet (resin film) exceeds 300 μm, retroreflective performance tends to be

5   lowered.   Also,   In   the   case   where   the   total   light transmittance of the resin sheet (resin film) is smaller than 20%, retroreflective performance tends to be lowered.

A resin constituting the resin sheet for forming the triangular pyramidal microprism pattern to be used in the

10   invention may be one or more kinds of resins selected from the group consisting of acrylic resin, polycarbonate resin, polystyrene resin, polyester resin, polyethylene resin, polypropylene resin, polyvinylchloride resin, polyarylate resin, polyurethane resin, epoxy resin, fluororesin, and

15   cellulose   resin.   Among   the   above,   acrylic   resin, polycarbonate resin, and polyarylate resin are preferred in the aspect of transparency of the resin, and processability on the prism elements. Acrylic resin and polyarylate resin are preferred in the aspect of weatherability.

20   A UV absorber selected from the group of benzotriazols, benzophenones, and triazines to enhance weatherability, a light   stabilizer   selected   from   hindered   amines,   an antioxidant   of   phenols   or   phosphates   to   enhance thermostability, or a lubricant such as montanic esters or

metal stearate salts to improve moldability may be added in the resin constituting the resin sheet (resin film) to be used in the invention according to needs.

An organic dye such as thioxanthenes, coumarins,
5 perylenes, methines, benzopyrans, thioindigos, or anthraquinones, or an organic pigment such as phthalocyanines may be added for coloring in the resin constituting the resin sheet (resin film) to be used in the invention according to needs.

10 An example of the method for producing the molding die (female die) having a metallic die in which an inverted pattern of the triangular pyramidal frustum type microprism pattern is concavely formed in a close-packed state is as follows. First, a male die in which a multitude of microsized
15 triangular pyramidal frustum protrusions are arrayed on a close-packed state is produced by: forming arrays of parallel grooves with a V-shape in cross section in a base member, which is made of a metallic material such as copper and has a smoothly grinded surface, with use of super hard bites (e.g.
20 a diamond bite, a tungsten carbide bite, or the like) having respective tipangles calculated based on an assumed triangular pyramidal shape, with repeated pitches in the respective directions (a_1, a_2, a_3), the predetermined depth of the groove (assumed height of the imaginary triangular
25 pyramid), and the respective angles between the adjacent side

surfaces in conformity to the targeted imaginary triangular

pyramidal configuration; and cutting off an upper portion of

the obtained triangular pyramid in such a manner that the

distance between the top surface (c) and the bottom surface

5   (d) is set to a predetermined height. Then, a nickel-made

female die with an inverse pattern to the pattern of the male

die is produced by electroforming, using the male die.

The method for transferring the reflective element

pattern (i.e. the triangular pyramidal frustum microprism

10   pattern) of the invention onto the resin sheet (resin film)

is not specifically limited. Various well-known methods such

as a method of heating and pressing a die, and a method of

forming a die on a roll or a belt, and transferring the

pattern of the die onto a resin sheet while feeding the resin

15   sheet may be adopted.

A preferred example of the structure of the inventive

retroreflective sheeting with the triangular pyramidal

frustum microprism elements is shown in FIG. 3, which is a

cross-sectional view.

20   Referring to FIG. 3, the reference numeral (3) denotes

a reflective element layer, in which the inventive triangular

pyramidal frustum microprism elements (retroreflective

elements) are disposed on one surface of the retroreflective

sheeting in a close-packed state; the reference numeral (2)

25   denotes a reflective element containing layer (prism sheet)

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containing the reflective elements. Generally, the reflective element layer (3) and the reflective element containing layer (2) are integrally formed. Alternatively, the layer (3) and the layer (2) may be independently formed one over the other.

5   The retroreflective sheeting of the invention may be provided with a surface protective layer (1) for protecting the retroreflective sheeting from physical or chemical damages such as contamination, scratches, or degradation due to light exposure or heat; and a backing sheet (backing film) (4) for

10   securing an air-tight sealing configuration on the backside surface of the reflective element (triangular pyramidal frustum prism element) layer, depending on the purpose of use or the environment for use. The retroreflective sheeting of the invention may be further provided with an adhesive layer

15   and a releaser layer on the outer surface of the backing sheet (backing film) (4) to attach the retroreflective sheeting to a structural member.

The resin constituting the surface protective layer (1) of the inventive retroreflective sheeting may be identical to

20   or different from the resin constituting the reflective element containing layer (prism sheet) (2). Alternatively, a UV absorber of the same kind as used in the reflective element containing layer (prism sheet) (2) may be added to enhance weatherability.

25   The backing film (backing sheet) (4) of the inventive

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retroreflective sheeting may have a plurality of airtight chambers on the backside surface of the reflective element (triangular pyramidal frustum prism element) layer (3) in which the air is sealed by firmly attaching the backing film

5 (backing sheet) (4) to the film (reflective element containing layer) (2) having the reflective element layer at the positions corresponding to protruding supports (5), which are locally formed on the backing film (backing sheet) by emboss processing.   Securing a boundary between the side

10 surfaces (slant surfaces) of the reflective element (triangular pyramidal frustum prism element) and the air enables to meet the total internal reflection requirement for the microprism elements, thereby enhancing the retroreflection.

15   The resin for use in the backing film (4) of the inventive retroreflective sheeting may be identical to or different from the resin for use in the prism sheet (2).

      The method for firmly attaching the backing sheet (4) to the reflective element containing layer (2) of the

20 inventive retroreflective sheeting is not specifically limited.   Well-known attaching methods such as a thermally-fusing-resin joining method, a thermosetting-resin joining method, a UV curing-resin joining method, or an electron-beam-curing-resin joining method may be applied.

25   Generally, it is known that the retroreflective

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performance of a retroreflective sheeting is lowered at a site where the reflective element layer (3) and the protruding support (5) are jointed to each other because the retroreflective sheeting cannot meet the total internal

5   reflection requirement for microprism elements at the jointed site.

In the inventive retroreflective sheeting with the triangular pyramidal frustum elements, in the case where the top surface (c) of the triangular pyramidal frustum element

10   is parallel to the bottom surface (b), as shown in FIG. 4, it is possible that: the backing film (4) is disposed adjacent the top surfaces (c) of the triangular pyramidal frustum elements without forming protruding supports by emboss processing; lowering of retroreflective performance is

15   suppressed because the total internal reflection requirement for the side surfaces of the triangular pyramidal frustum elements is not obstructed; and enhanced adhesiveness is obtained.

The inventive retroreflective sheeting with the

20   triangular pyramidal frustum prism elements does not have apex portions as the conventional triangular pyramid type prism elements, and therefore, there is no or less likelihood that the retroreflective performance varies due to abrasion of the apex or deformation of the prism, in storage of the

25   resin film (resin sheet) formed with the prism pattern, or in

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firmly attaching the backing sheet.

As mentioned above, the inventive retroreflective sheeting having the features that the retroreflective layer containing the triangular pyramidal frustum prism elements in

5 a close-packed state is formed on one surface of the retroreflective sheeting, and that the plural airtight chambers are provided with use of the backing film provides superior incident angularities and superior direction characteristics with no or less likelihood of halation even

10 at a small incident angle. Thus, the inventive retroreflective sheeting with the triangular pyramidal frustum prism elements are advantageously used for signboards such as road signboards and construction site signboards, car license plates of automotive vehicles such as automobiles and

15 motorcycles, safety materials such as collision warning signboards, clothing, and life jackets.

EXAMPLES

In the following, the invention will be described in

20 further details by illustrating examples and comparative examples, which, however, do not delimit the invention.

(Examples 1 to 7 and Comparative Examples 1 to 7)

Retroreflective sheetings, in which triangular pyramidal frustum prism patterns were formed on acrylic resin

25 sheets (product of Kaneka Corporation, Sunduren SD009NCT:

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thickness of 200 μm, total light transmittance of 92%), were produced with use of a female die, in which triangular pyramidal frustum prism-like recesses with the dimensions shown in Table 1 were arrayed in a close-packed state.

5   Specifically, prepared were diamond bites with the respective predetermined tipangles corresponding to the respective angles between the bottom surface and the adjacent side surfaces, which were calculated based on the dimensions shown in Table 1, and then, a copper-made male die was

10   produced, in which a multitude of triangular pyramidal frustum prism-like protrusions with the height of 80 μm were arrayed in a close-packed state according to the following steps. Subsequently, a nickel-made female die formed with an inverse pattern to the pattern of the copper-made male die

15   was produced by electroforming, using the male die. For instance, in Example 1, prepared were diamond bites of three kinds with the tipangles of 58 degrees, 86 degrees, and 92 degrees, respectively; and then arrays of parallel grooves with a V-shape in cross section were cut with a repeated

20   pattern on a smoothly grinded surface of a copper plate of 200 mm × 200 mm, with use of the diamond bite with the tipangle of 58 degrees so that the repeated pitch was 225 μm, and the depth of the groove was 100 μm. Thereafter, arrays of parallel grooves with a V-shape in cross section were cut

with a repeated pattern in the copper plate, with use of the diamond bite with the tipangle of 86 degrees so that the repeated pitch was 230 μm, the depth of the groove was 100 μm, and the angle of the intersection with the side a_1 was 63

5   degrees. Then, arrays of parallel grooves with a V-shape in cross section were formed with a repeated pattern in the copper plate, with use of the diamond bite with the tipangle of 92 degrees so that the repeated pitch was 215 μm, the depth of the groove was 100 μm, the angle the intersection

10   with the side a_1 was 66 degrees, and the angle the intersection with the side a_2 was 51 degrees. Then, upper portions of the obtained triangular pyramidal protrusions were cut off so that an upper flat plane of a triangular pyramidal frustum to be obtained was made parallel to a lower

15   flat plane thereof, and that the distance between the upper flat plane and the lower flat plane was 80 μm.

Subsequently, using the obtained female die, the triangular pyramidal frustum prism pattern was transferred to the acrylic film by heat press, whereby retroreflective

20   sheetings each of 200 mm $\times$ 200 mm were produced. The below-mentioned evaluations were conducted with respect to the obtained retroreflective sheetings.

(Comparative Example 8)

The below-mentioned evaluations were conducted with

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respect to a glass beads type retroreflective sheeting i.e. Scotchlite #8910 (product of Sumitomo 3M Limited).

(Comparative Example 9)

The below-mentioned evaluations were conducted with respect to Scotchlite Diamond LDP Grade White (product of Sumitomo 3M Limited).

(Evaluation Method)

<Calculation of Coefficient of retroreflection>

Retroreflective performance and the like were evaluated with respect to the retroreflective sheetings produced in Examples and Comparative Examples based on the following conditions.

The following items were measured according to JIS Z8714 based on the layout drawing shown in FIG. 5, and a coefficient of retroreflection of the retroreflective sheetings each was calculated in accordance with the formulae 1 and 2.

$$I = Er \cdot d^2 \qquad \qquad \ldots (1)$$

$$R' = \frac{I}{En \cdot A} \qquad \qquad \ldots (2)$$

where R': coefficient of retroreflection (unit: $Cd/Lx \cdot m^2$)

I: luminance (unit: Cd) of a sample observed from a receiving position

Er: illuminance (unit: Lx) on the optical receiver at the layout position (incident angle α, observation angle β)

shown in FIG. 5

En: illuminance (unit: Lx) on a flat plane perpendicular to incident' light at a center position of the sample

5   d: distance (unit: m) from the center on the sample surface to the optical receiver

A: area (unit: m^2) of the sample surface

(1) Halation and Retroreflective Performance

The retroreflective performance was evaluated based on

10   a coefficient (A1) of retroreflection in a criterion of the observation angle of 0.2 degrees and the incident angle of 5 degrees. A larger coefficient of retroreflection indicates better retroreflective performance, but a coefficient of retroreflection of 900Cd/Lx·m^2 or more was measured to cause

15   halation.

The measurement criterion on halation was as follows:

○ : coefficient of retroreflection of smaller than 900Cd/Lx·m^2

✕ : coefficient of retroreflection of 900Cd/Lx·m^2 or

20   more

(2) Incident Angularities

Evaluations were made based on two criteria, wherein one criterion was the observation angle of 0.2 degrees and the incident angle of 5 degrees, and the other criterion was

the observation angle of 1 degree and the incident angle of 30 degrees. Coefficients (A1 and B1) of Retroreflection in the respective criteria were calculated, and the ratio (B1/A1) of coefficients of retroreflection was defined as an

5   index on incident angularities. A larger index indicates better incident angularities.

(3) Direction Characteristics

In measuring a coefficient of retroreflection in a criterion of the observation angle of 1 degree and the

10   incident angle of 30 degrees, a coefficient (B2) of retroreflection was calculated when the prism sheet is rotated by a rotation angle θ=90 degrees, as shown in FIG. 6. The ratio (B2/B1) of coefficients of retroreflection was defined as an index on direction characteristics. A larger

15   index indicates better direction characteristics.

The evaluation results on Examples and Comparative Examples are shown in Table 2.

The inventive retroreflective sheetings with the triangular pyramidal frustum microprism elements as the

20   reflective elements exhibit superior incident angularities and superior direction characteristics with no or less likelihood of halation even at a small incident angle, as shown in Table 2.

Table 1

		Examples							Comparative Examples						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
triangular bottom surface(b)	a_1 (μm)	225	80	350	200	225	225	225	20	500	400	250	350	350	350
	a_2 (μm)	230	120	350	200	230	225	230	20	500	400	250	350	350	350
	a_3 (μm)	215	120	250	200	215	225	215	25	500	50	150	350	300	350
	difference between longest and shortest sides (μm)	15	40	100	0	15	0	15	5	0	350	100	0	50	0
length of edge	d_1 (μm)	210	110	330	180	210	210	210	40	380	150	450	340	100	250
	d_2 (μm)	155	105	350	180	155	155	155	30	380	145	400	350	80	100
	d_3 (μm)	170	100	335	180	170	170	170	40	380	130	420	350	100	250
	length of longest edge (d) (μm)	210	110	350	180	210	210	210	40	380	150	450	350	100	250
	difference between longest and shortest edges (μm)	40	10	20	0	40	40	40	10	0	20	50	10	20	150
distance between bottom surface(b) and top surface(c)	e_1 (μm)	80	80	240	85	70	80	75	20	240	90	200	10	60	20
	e_2 (μm)	80	80	240	85	70	80	85	20	240	90	200	10	60	20
	e_3 (μm)	80	80	240	85	70	80	80	20	240	90	200	10	60	20
	longest distance (e)(μm)	80	80	240	85	70	80	85	20	240	90	200	10	60	20
angle between adjacent side surfaces	f_1(degrees)	90	87	92	90	90	90	90	90	90	87	92	89	100	82
	f_2(degrees)	90	87	92	90	90	90	90	90	90	87	92	89	100	82
	f_3(degrees)	90	87	92	90	90	90	90	90	90	87	92	89	100	82

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Table 2

		Examples							Comparative Examples									acceptable criterion
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	
coefficient of retroreflection	A1 observation angle: 0.2° incident angle: 5°	550	850	430	500	430	380	500	920	150	350	25	15	20	20	70	1030	
	B1 observation angle: 1° incident angle:30°	400	760	330	415	310	260	360	770	30	50	10	5	10	10	28	40	
	B2 observation angle: 1° incident angle: 30°	365	720	310	340	285	210	260	510	10	30	8	1	7	5	28	25	
halation		○	○	○	○	○	○	○	×	○	○	○	○	×	○	○	×	A1<900
incident angularities (B1/A1)		0.73	0.89	0.77	0.83	0.72	0.68	0.73	0.84	0.2	0.14	0.40	0.33	0.50	0.50	0.40	0.04	
direction characteristics (B2/B1)		0.9	0.8	0.9	0.8	0.9	0.8	0.7	0.7	0.3	0.6	0.8	0.2	0.7	0.5	1.0	0.6	0.7 or more

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Industrial Applicability

The inventive retroreflective sheeting having the features that the triangular pyramidal frustum prism elements
5 are disposed on one surface of the retroreflective sheeting in a close-packed state, and that the plural airtight chambers are defined with use of the backing film exhibits superior incident angularities and superior direction characteristics with no or less likelihood of halation even
10 at a small incident angle. Thus, the inventive retroreflective sheeting with the triangular pyramidal frustum prism elements is advantageously used for signboards such as road signboards and construction site signboards, car license plates of automotive vehicles such as automobiles and
15 motorcycles, safety materials such as collision warning signboards, clothing, and life jackets.